

WELL 16/1-4		Log run 2A and 2B		FMT-SAMPLING							
Test No.	Depth m MD	Depth m TVD	Hydrostatic press. bef. kPa	HP-Form. pressure kPa	SG-Form. pressure kPa	Hydrostatic press. aft. kPa	Drawdown pressure kPa	Fill time sec.	Temp. °C	Good seal Y/N	Remarks
3	1867.5										<p><b>Sample run 2A</b>            10 liter chamber            gas vol: 0.28 m<sup>3</sup>            oil vol: film            water vol: 5 litre            Opening pressure 8620 kPa            C1 = 81.88% nC4 = 0.93%            C2 = 11.57% iC5 = 0.05%            C3 = 4.60% nC5 = 0.00%            iC4 = 0.97% CO<sub>2</sub> &lt; 0.1%            H<sub>2</sub>S = 0 ppm</p> <p>(fluid lost due to leak)            Salinity 51000 mg/l            pH 7.7, T.hardn. 1600 mg/l</p> <p>* Salinity as the mudfiltrate            * pH as the mudfiltrate            * T.hardness 800-900 mg/l higher            * Thin film of transparent HC-smelling fluid on top of the fluid</p> <p>1 gallon chamber leaking.</p>
1	1867.4		23406	19164	19467	23421	16421				<p><b>Sample run 2B</b>            10 liter chamber            gas vol 0.28 m<sup>3</sup>            oil vol film            water vol. 6 litre            Opening pressure 8960 kPa            C1 = 84.57% nC4 = 0.62%            C2 = 9.98% iC5 = 0.11%            C3 = 4.17% nC5 = 0.38%            iC4 = 0.47% CO<sub>2</sub> &lt; 0.1%            H<sub>2</sub>S = 0 ppm</p> <p>1 gallon chamber            gas vol 0.23 m<sup>3</sup>            oil vol ?            water vol. 0.9 litre            Opening pressure 8960 kPa.            Sealed and sent onshore.</p> <p>For detailed analysis of FMT samples, see separate Geco report "16/1-4 Transfer and Analysis of FMT Sample" and Statoil report "Well 16.1-4 FMT Sample, Hydrocarbon and Water Analysis".</p>

Table 3.3.2



**SECTOR FOR GEOTECHNOLOGY  
Geochemistry Department**

Grading .
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<b>Title</b> GEOCHEMICAL REPORT FOR WELL NOCS 16/1-4		
<b>Requested by</b> Øystein Hovden, LETETEK-BO	<b>Project</b>	
<b>Date</b> 31.08.93	<b>No. of pages</b>	<b>No. of enclosures</b>

<b>Keywords</b>  geochemistry, source rock, maturity, migrated hydrocarbons, gas, condensate, well 16/1-4
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<b>Prepared by</b>  Geolab Nor BA-93-2058-1 28 SEPT. 1993 <b>REGISWERT</b> <b>OLJEDIREKTORATET</b> Text operator
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**GEOCHEMICAL REPORT FOR  
WELL NOCS 16/1-4**

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## Chapter 1

# INTRODUCTION

The geochemical study included investigation of potential source rocks, ranging from Tertiary claystones to Shetland Gp. claystones. Potential reservoir intervals were also analysed, with special emphasis on Eocene sandstones and the Upper Cretaceous reservoir rocks. One gas sample recovered from 1867.5 m depth and FMT sample ZC 331461 recovered from the basement(?) sandstones recovered from the same RFT run 2A, were analysed. Both screening analyses and follow-up analyses were performed in order to evaluate source rocks and migrated hydrocarbons. The report is divided into chapters and sections, which treat source rocks, thermal maturity and migrated hydrocarbons individually. Within the chapters the results are discussed in a stratigraphic context.

### 1.1 General Well Information

The well NOCS 16/1-4 is situated in the Norwegian North Sea sector, north-east of the Sleipner Fields. The 16/1 block and adjoining Sleipner fields are shown in Figure 1. The well penetrated the Upper Cretaceous Shetland Gp. and went into the Devonian/Permian (?). All depths are given relative to KB unless otherwise specified.

## 1.2 Analytical Program

The analytical program for well NOCS 16/1-4 was based on the samples selected by Statoil for screening and detailed follow-up analysis. The number of samples for the individual analyses are listed below:

<u>Analysis type</u>	<u>No of samples</u>	<u>Figures</u>	<u>Tables</u>
Lithology description	24	2	1
TOC	17	3	1,2a-b
Rock-Eval pyrolysis	24	4,5a-b,9,11,12	2a-b
Iatroscan TLC/FID	14		3a-b
Pyrolysis GC (GHM, S <sub>2</sub> )	5	6a-c	4
Visual kerogen microscopy	4	7	5,6
Vitrinite reflectance*	13	10a-b	7
Thermal extraction GC (GHM, S <sub>1</sub> )	4	13a-b	
Whole Oil GC	1	17	8
Soxhlet Extraction of organic matter	7		
MPLC/HPLC separation	11	14	9a-e
Saturated hydrocarbon GC	9	15	10
Aromatic hydrocarbon GC	9	16	11
GC - MS of saturated HC	7	8,18,19,22	12a-f
Isotope composition C <sub>15</sub> + fractions	7	20,21	13a-b
Isotope composition kerogen conc.	1	21	13a
Gas GC and isotope GC	1	23a-c	14a-b
Oil API-gravity and topping	1		15

\* Vitrinite reflectance measurements were performed by IFE. The IFE report no. is IFE/KR/F-93/120.

## **Abbreviations**

### **List of abbreviations used for lithology description (sorted alphabetically)**

ang	= angular
bar	= Baryte (mud additive)
bit	= bituminous
bl	= blue/blueish
blk	= black
br	= brittle
brn	= brown/brownish
Ca	= Carbonate (limestone/chalk/dolomite/siderite)
calc	= calcareous
carb	= carbonaceous
cem	= cement used as additive (under "cont") or to describe cemented S/Sst
Chert	= Chert
chk	= Chalk/chalky
cly	= clayey/shaly
cngl	= conglomeratic
Coal	= Coal
Coal-ad	= Coal-like additive (e.g. chromlignosulfonate)
Congl	= Conglomerat
Cont	= Contamination(s)
crs	= coarse grained
dd	= dried drilling mud
dol	= Dolomite/dolomitic
drk	= dark (colour)
dsk	= dusk/dusky (colour)
evap	= Salt/Gypsum/Halite (natural "Other" or as additive "Cont")
f	= fine grained
fe	= ferruginous
fib	= fibres (mud additive/contamination)
fis	= fissile
fos	= fossiliferous
glauc	= glauconite/glauconitic
gn	= green/greenish
gy	= grey/greyish
hd	= hard
ign	= Igneous (material derived from igneous source)
Kaolin	= Kaolin(ite)
kln	= kaolinitic
l	= loose
lam	= laminated/laminae
lt	= light (colour)
m	= medium (colour or grain size)
Marl	= Marl (calcareous claystone/mudstone)
mic	= micaceous
Mica-ad	= Mica used as mud additive

mrl	= marly
No Mat.	= No material left over after washing
ns	= nutshells (mud additive)
ol	= olive
ool	= Oolite/oolitic
or	= orange
Other	= Other lithology/mineral, specified after this word
pi	= pink/pinkish
pl	= pale (colour)
prp	= paint/rust/plastic contaminations/additives
pu	= purple
pyr	= Pyrite/pyritic
red	= red/reddish
rnd	= round/rounded
s	= sandy
sft	= soft
S/Sst	= Sand and/or sandstone
Sh/Clst	= Shale and/or claystone
sid	= Siderite/sideritic
sil	= siliceous/cherty
silt	= silty
Siltst	= siltstone
st	= stained (with natural oil or oil-like additive)
tar-ad	= Tar-like additive (e.g. "Black Magic")
trbfgs	= turbodrilled fragments
Tuff	= Tuff
tuff	= tuffaceous
v col	= various colours
w	= white
wx	= waxy
y	= yellow/yellowish



## Experimental

### Headspace Gas Analysis

The analysis is performed using a Perkin Elmer 8310 gas chromatograph with a 50 m Plot fused silica  $Al_2O_3/KCL$  column, loop injector and flame ionization detector. Nitrogen is used as carrier gas and the column is run from 70°C to 200°C, at a rate of 12°C/min. Final hold time is 5 min.

Two  $cm^3$  of headspace gas are removed from each sample can for chromatographic analysis of the  $C_1$  to  $C_7$  range of hydrocarbons.

### Occluded Gas Analysis

The gas chromatograph used for this analysis is identical to that used for headspace gas analysis and is operated under the same conditions.

The canned samples are washed in thermostat-controlled water to remove drilling contaminants and sieved on a 2 mm mesh sieve to remove large, caved rock fragments. An aliquot (ca 25 mg) of sieved sample is crushed with 25  $cm^3$  water in an airtight ball mill. After crushing, 2  $cm^3$  of the released gas are removed from the ball mill for gas chromatographic analysis.

### Total Organic Carbon (TOC) and Total Carbon Analysis

This analysis is performed using a LECO CS244 Carbon Analyser.

Hand-picked lithologies from cuttings samples are crushed with a mortar and pestle and approximately 200 mg (50 mg for coals) are accurately weighed into LECO crucibles. The samples are then treated three times with 10 % hydrochloric acid to remove oxidized (carbonate) carbon, and washed four times with distilled water. The samples are dried on a hotplate at 60 - 70°C before analysis of total organic carbon.

Total carbon is also analysed on the same instrument using approximately 200 mg of untreated crushed whole rock. Oxidized (carbonate) carbon is calculated by weight difference.

Total organic carbon can also be analysed on the Rock-Eval II Pyrolyser during the normal run of the instrument.

### **Rock-Eval Pyrolysis**

This analysis is performed by using a Rock-Eval II Pyrolyser. Approximately 100 mg crushed whole rock is analysed. The sample is first heated at 300°C for three min in an atmosphere of helium to release the free hydrocarbons present (S1 peak) and then pyrolysed by increasing the temperature from 300°C to 600°C (temp. gradient 25°C/min) (S2 peak). Both the S1 and S2 yields are measured using a flame ionization detector (FID). In the temperature interval between 300°C and 390°C, the released gases are split and a proportion passed through a carbon dioxide trap, which is connected to a thermal conductivity detector (TCD). The value obtained from the TCD corresponds to the amount of oxygen contained in the kerogen of the sample and is reported as the S3 peak.

The Rock-Eval II Pyrolyser also analyses the TOC of each sample during the normal run of the instrument.

### **latroscan**

Saturates, aromatics, polars and asphaltenes are qualitatively and quantitatively assessed using latroscan TLC-FID and employing Chromarod S-III rods. The crushed approx. 3 g. rock samples are extracted for a period of 24 hours with frequent manual shaking of the samples, using a mixture of DCM/MeOH. 1-3 µl of the solution is spotted on the pre-activated rods, using an auto-spotter. The rods are developed in n-hexane (35 mins.) as mobile phase, followed by toluene (14 mins.) and DCM/MeOH (4 mins.) with 2 minutes air drying between every stage. The developed rods are introduced in a 60°C oven for 90 seconds. The rods are analysed using latroscan and

data collected and processed using Multichrom data system.

### **Thermal Extraction/Pyrolysis Gas Chromatography**

The instrument used for this analysis is a Varian 3400 Gas Chromatograph interfaced to a pyrolysis oven (the pyrolyser). Up to 15 mg of whole rock sample is loaded on the pyrolyser and heated isothermally, at 300°C, for 4 min, during which time thermal extraction of the free hydrocarbons occurs (equivalent to the S1 peak of the Rock-Eval). The released gases pass to a 25 m OV1 column with a liquid nitrogen-cooled trap.

After 4 min the pyrolysis oven is temperature programmed up to 530°C, at a rate of 37°C/min, causing bound hydrocarbons to be released from the kerogen (equivalent to the S2 peak of the Rock-Eval). The released gases pass to a 25 m OV1 column with a liquid nitrogen-cooled trap.

The temperature program of the gas chromatograph oven, in which the columns are housed is -10°C to 290°C at a rate of 6°C/min.

Both the columns are linked to a FID.

### **Solvent Extraction of Organic Matter (EOM)**

The samples are extracted using a Tecator Soxtec HT-System. Carefully weighed samples are taken in a pre-extracted thimble. Some activated copper is added to the extraction cup and dichloromethane/methanol (93/7) is used as an extraction solvent. The samples are boiled for 1 hour and then rinsed for 2 hours. If the samples contain more than 10 % TOC, then the whole procedure is repeated once. The resulting solution is filtered and the solvent removed by rotary evaporation (200 mb, 30°C). The amount of EOM is gravimetrically established.

## Removal of Asphaltenes

The EOM is dissolved in tetrahydrofuran in a flask and n-pentane is added to precipitate the asphaltenes. The solution is then stored in the dark and at ambient temperature for at least 8 hours. The solution is then filtered (Baker 10-spe system) and the precipitated asphaltenes returned to the original flask by dissolution in dichloromethane. The solvent is removed by rotary evaporation at 200 mB and 30°C.

## Chromatographic Separation of deasphalted EOM

Chromatographic separation is performed using an MPLC system developed by the company. The EOM (minus asphaltenes) is injected into the MPLC and separated using hexane as an eluent. The saturated and aromatic hydrocarbon fractions are collected and the solvent removed using a rotary evaporator at 30°C. The fractions are then transferred to small pre-weighed vials and evaporated to dryness in a stream of nitrogen. The vials are re-weighed to obtain the weights of both the saturated and the aromatic fractions. The weight of the NSO fraction which is retained on the column, is obtained by weight difference.

## Gas Chromatographic Analyses

### Saturated hydrocarbon fractions:

The instrument used for this analysis is a PERKIN ELMER 8320 Gas Chromatograph equipped with an FID detector and an OV1 column. The carrier gas is helium and the temperature program runs from 80°C to 300°C at a rate of 4°C/min. Final hold time is 20 mins. The saturated hydrocarbon fraction is diluted by 1:30 and a 1 microlitre aliquot of this is injected into the instrument.

### Aromatic hydrocarbon fractions:

The instrument used is a Varian 3400 Gas Chromatograph with a 25 m SE 54 capillary column, split injector and a column splitter leading to FID and FPD detectors, which allows simultaneous analysis of co-eluting hydrocarbons and sulphur compounds. The carrier gas is helium and the temperature program runs from 40°C to 290°C at a rate of 4°C/min. Final hold time is 10 mins. The aromatic hydrocarbon fraction is diluted by 1:30 and a 1 microlitre aliquot of this is injected into the instrument.

### **Whole Oil/Whole Extract**

Whole oil chromatograms are determined on a Perkin Elmer Sigma 2000 gas chromatograph fitted with a split injector, 25 m SE54 capillary column and effluent splitter connected to FID and FPD detectors allowing simultaneous determination of hydrocarbons and sulphur compounds. Approximately 0.1 microlitres of whole oil are injected and the temperature program on the chromatograph runs from -10°C to 300°C at 4°C/min.

### **Vitrinite Reflectance Analysis**

Samples to be analysed for vitrinite reflectance are ground to small granules (if necessary) using a pestle and mortar and are then mounted in a fast setting resin. The resin blocks are first ground flat using a coarse corundum paper to expose the rock granule surfaces and then with three finer grades of corundum paper to improve these surfaces and reduce scratches. The blocks are finally polished on a rotating Selvyt-covered lap using three grades of diamond suspension fluid. An appropriate lubricant is used when necessary.

Reflectance measurements are made under oil immersion at 546 nm using a Zeiss Universal Photo microscope II equipped with a HP 9000 series computer system. The polished blocks are mounted on the microscope stage and scanned manually in order to locate and measure particles of vitrinite. An attempt is made to obtain readings from 15-20 individual particles per sample, but this is not always possible in samples with low amounts of phytoclasts.

### **Visual Kerogen Microscopy**

Kerogen concentrates are obtained from samples prepared by HCl and HF digestion followed by zinc bromide flotation to remove pyrite and other heavy mineral residues. The cleaned concentrates are mounted on slides by smearing, these being analysed

microscopically in transmitted white light and UV light (530 nm barrier filter) to determine the Spore Colour or Thermal Alteration Indices (SCI or TAI) and the colour and intensity of spore fluorescence. The spore colour index, backed by spore fluorescence, is used as an alternative maturity parameter to verify the results obtained from vitrinite reflectance.

Fluorescence Colour	Colour Index	Corresp. Vitrinite Reflectance
Green	1	0.2 %
Green/yellow	2	0.2-0.3 %
Yellow	3	0.3 %
Yellow/orange	4	0.4 %
Light orange	5	0.5 %
Moderate-orange	6	0.6 %
Dark orange	7	0.8 %
Dark orange/red	8	1.0 %
Spore fluorescence extinction	9	1.3 %

NB. This table only provides a rudimentary correlation as vitrinite reflectance and spore fluorescence colour are both independently affected by factors such as depositional environment and catenogenic history.

#### Combined Gas Chromatography - Mass Spectrometry (GC-MS)

The GC-MS analyses are performed on a VG TS250 system interfaced to a Hewlett Packard 5890 gas chromatograph. The GC is fitted with a fused silica SE54 capillary column (40 m x 0.22 mm i.d.) directly into the ion source. Helium (12 psi) is used as carrier gas and the injections are performed in splitless mode. The GC oven is programmed from 45°C to 150°C at 35°C/min, at which point the programme rate is 2°C/min up to 310°C where the column is held isothermally for 15 min. For the aromatic hydrocarbons, the GC oven is programmed from 50°C to 310°C at 5°C/min. and held isothermally at 310°C for 15 min. The mass spectrometer is operated in electron impact (EI) mode at 70 eV electron energy, a trap current of 500 uA and a source temperature of 220°C. The instrument resolution used is 2500 (10 % value).

The data system used is a VG PDP11/73 for acquiring data, and a Vax station 3100 for peak processing the data. The samples are analysed in multiple ion detection



mode (MID) at a scan cycle time of approximately 1.1 sec.

Calculation of peak ratios is performed from peak heights in the appropriate mass fragmentograms.

## Saturated Fractions

### Terpanes

The most commonly used fragment ions for detection of terpanes are M/Z 163 for detection of 25,28,30 trisnormoretane or 25,28,30 trisnorhopane, M/Z 177 for detection of demethylated hopanes or moretanes, M/Z 191 for detection of tricyclic, tetracyclic- and pentacyclic terpanes and M/Z 205 for methylated hopanes or moretanes. The molecular ions M/Z 370 and 384 are also recorded for identification of C<sub>27</sub> and C<sub>28</sub> triterpanes respectively.

### Steranes

The most commonly used fragment ions for detection of steranes are M/Z 149 to distinguish between 5 $\alpha$  and 5 $\beta$  steranes, M/Z 189 and 259 for detection of rearranged steranes, M/Z 217 for detection of rearranged and normal steranes and M/Z 218 for detection of 14 $\beta$ (H) 17 $\beta$ (H) steranes.

The M/Z 231 fragment ion is used to detect possible aromatic contamination of the saturated fraction. It is also used for detection of methyl steranes.

## Aromatic Fractions

### Alkyl-substituted Benzenes

The M/Z 106 fragment ion is often used to detect the alkyl-substituted benzenes. It is especially useful for the detection of di-substituted benzenes. M/Z 134 can also be used for the detection of C<sub>4</sub>-alkylbenzenes, but benzothiophene will also give a signal with this fragment ion.

### Naphthalenes

Methyl naphthalenes are normally detected by the M/Z 142 fragment ion, while C<sub>2</sub>-naphthalenes are detected by M/Z 156 and C<sub>3</sub>-naphthalenes by M/Z 170.

### Benzothiophenes and Dibenzothiophenes

Benzothiophene can be detected, as mentioned above, by M/Z 134. The M/Z 184 fragment ion is used to detect the dibenzothiophenes. The M/Z 198 and M/Z 212 fragment ions are used for methyl-substituted dibenzothiophenes and dimethyl-substituted dibenzothiophenes respectively.

### Phenanthrenes

Phenanthrene is detected using the M/Z 178 fragment ion. Anthracene will, if present, also give a signal in the M/Z 178 fragment ion. Methyl-substituted phenanthrenes give signals in the M/Z 192 fragment ion, while the M/Z 206 fragment ion shows the dimethyl-substituted phenanthrenes and the M/Z 220 fragment ion shows the C<sub>3</sub> substituted phenanthrenes.

## Aromatic Steranes

Monoaromatic steranes are detected using the M/Z 253 fragment ion, while the triaromatic steranes are detected using the M/Z 231 fragment ion.

**Mass Fragmentograms representing Terpanes**  
**(M/Z 163, 177, 191, 205, 370, 384, 398, 412 and 426)**

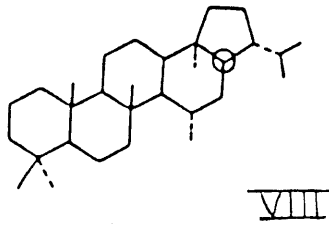
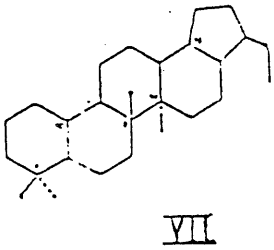
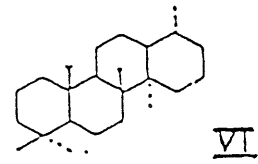
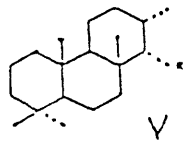
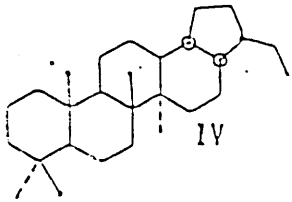
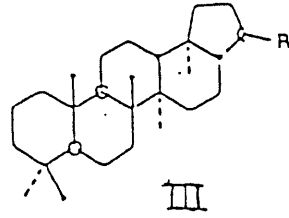
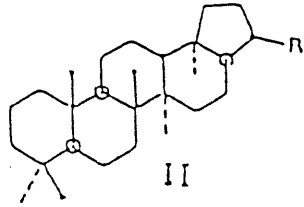
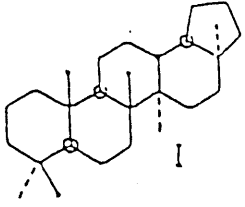
Peak Identification: ( $\alpha$  and  $\beta$  refer to hydrogen atoms at C-17 and C-21 respectively unless indicated otherwise)

27Ts	18 $\alpha$ trisnorneohopane (T <sub>s</sub> )	C <sub>27</sub> H <sub>44</sub>	( I )
27Tm	17 $\alpha$ trisnorhopane (T <sub>m</sub> )	C <sub>27</sub> H <sub>46</sub>	( II, R=H )
28 $\alpha\beta$	bisnorhopane	C <sub>28</sub> H <sub>48</sub>	( IV )
25nor30 $\alpha\beta$ *	norhopane	C <sub>29</sub> H <sub>46</sub>	
29 $\alpha\beta$	$\alpha\beta$ norhopane	C <sub>29</sub> H <sub>50</sub>	( II, R=C <sub>2</sub> H <sub>5</sub> )
29Ts	norneohopane	C <sub>29</sub> H <sub>50</sub>	
29 $\beta\alpha$	$\beta\alpha$ norhopane	C <sub>29</sub> H <sub>50</sub>	( III, R=C <sub>2</sub> H <sub>5</sub> )
30 $\alpha\beta$	$\alpha\beta$ hopane	C <sub>30</sub> H <sub>52</sub>	( II, R=i-C <sub>3</sub> H <sub>7</sub> )
30O	Oleanane	C <sub>30</sub> H <sub>52</sub>	
30 $\beta\alpha$	$\beta\alpha$ hopane	C <sub>30</sub> H <sub>52</sub>	( III, R=i-C <sub>3</sub> H <sub>7</sub> )
31 $\alpha\beta$ S	22S $\alpha\beta$ homohopane	C <sub>31</sub> H <sub>54</sub>	( II, R=i-C <sub>4</sub> H <sub>9</sub> )
31 $\alpha\beta$ R	22R $\alpha\beta$ homohopane	C <sub>31</sub> H <sub>54</sub>	( II, R=i-C <sub>4</sub> H <sub>9</sub> )
30G	gammacerane	C <sub>30</sub> H <sub>52</sub>	
31 $\beta\alpha$	$\beta\alpha$ homohopane	C <sub>31</sub> H <sub>54</sub>	( III, R=i-C <sub>4</sub> H <sub>9</sub> )
32 $\alpha\beta$ S	22S $\alpha\beta$ bishomohopane	C <sub>32</sub> H <sub>56</sub>	( II, R=i-C <sub>5</sub> H <sub>11</sub> )
32 $\alpha\beta$ R	22R $\alpha\beta$ bishomohopane	C <sub>32</sub> H <sub>56</sub>	( II, R=i-C <sub>5</sub> H <sub>11</sub> )
33 $\alpha\beta$ S	22S $\alpha\beta$ trishomohopane	C <sub>33</sub> H <sub>58</sub>	( II, R=i-C <sub>6</sub> H <sub>13</sub> )
33 $\alpha\beta$ R	22R $\alpha\beta$ trishomohopane	C <sub>33</sub> H <sub>58</sub>	( II, R=i-C <sub>6</sub> H <sub>13</sub> )
34 $\alpha\beta$ S	22S $\alpha\beta$ tetrakishomohopane	C <sub>34</sub> H <sub>60</sub>	( II, R=i-C <sub>7</sub> H <sub>15</sub> )
34 $\alpha\beta$ R	22E $\alpha\beta$ tetrakishomohopane	C <sub>34</sub> H <sub>60</sub>	( II, R=i-C <sub>7</sub> H <sub>15</sub> )
35 $\alpha\beta$ S	22S $\alpha\beta$ pentakishomohopane	C <sub>35</sub> H <sub>62</sub>	( II, E=i-C <sub>8</sub> H <sub>17</sub> )
35 $\alpha\beta$ R	22E $\alpha\beta$ pentakishomohopane	C <sub>35</sub> H <sub>62</sub>	( II, R=i-C <sub>8</sub> H <sub>17</sub> )
23/3	Tricyclic terpane	C <sub>23</sub> H <sub>42</sub>	( V, R=i-C <sub>4</sub> H <sub>9</sub> )
24/3	Tricyclic terpane	C <sub>24</sub> H <sub>44</sub>	( V, R=i-C <sub>5</sub> H <sub>11</sub> )
25/3	Tricyclic terpane (17R, 17S)	C <sub>25</sub> H <sub>66</sub>	( V, R=i-C <sub>6</sub> H <sub>13</sub> )
24/4	Tetracyclic terpane	C <sub>24</sub> H <sub>42</sub>	( VI )
26/3	Tricyclic terpane (17R, 17S)	C <sub>26</sub> H <sub>48</sub>	( V, R=i-C <sub>7</sub> H <sub>15</sub> )

21/3	Tricyclic terpane	$C_{21}H_{38}$	( V, R=C <sub>2</sub> H <sub>5</sub> )
22/3	Tricyclic terpane	$C_{22}H_{40}$	( V, R=C <sub>3</sub> H <sub>7</sub> )
25 nor28 $\alpha\beta$ *	25,28,30-trisnorhopane/moretane	$C_{27}H_{46}$	( VII)
30d	$\alpha\beta$ diahopane	$C_{30}H_{52}$	( VIII)

\* Also identified and quantified in M/Z 177 fragmentograms.

STRUCTURES REPRESENTING TERPANES



**Mass Fragmentograms representing Steranes**  
(M/Z 149, 189, 217, 218, 259, 372, 386, 400 and 414)

Peak Identifications:  $\alpha$  and  $\beta$  refer to hydrogen atoms at C-5, C-14 and C-17 in regular steranes and at C-13 and C-17 in diasteranes).

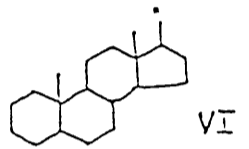
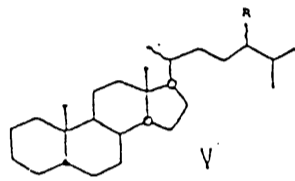
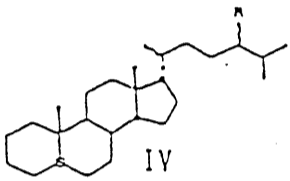
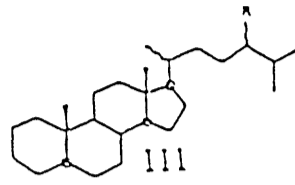
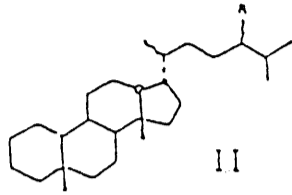
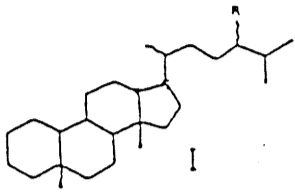
21 $\alpha$	5 $\alpha$ sterane	C <sub>21</sub> H <sub>36</sub>	( VI, R=C <sub>2</sub> H <sub>5</sub> )
22 $\alpha$	5 $\alpha$ sterane	C <sub>22</sub> H <sub>38</sub>	( VI, R=C <sub>3</sub> H <sub>7</sub> )
27d $\beta$ S	20S $\beta\alpha$ diacholestane	C <sub>27</sub> H <sub>48</sub>	( I, R=H)
27d $\alpha$ R	20R $\beta\alpha$ diacholestane	C <sub>27</sub> H <sub>48</sub>	( I, R=H)
27d $\alpha$ R	20S $\alpha\beta$ diacholestane	C <sub>27</sub> H <sub>48</sub>	( II, R=H)
27d $\alpha$ S	20R $\alpha\beta$ diacholestane	C <sub>27</sub> H <sub>48</sub>	( II, R=H)
28d $\beta$ S	20S $\beta\alpha$ 24-methyl-diacholestane	C <sub>28</sub> H <sub>50</sub>	( I, R=CH <sub>3</sub> )
28d $\beta$ R	20R $\beta\alpha$ 24-methyl-diacholestane	C <sub>28</sub> H <sub>50</sub>	( I, R=CH <sub>3</sub> )
28d $\alpha$ R	20S $\alpha\beta$ 24-methyl-diacholestane	C <sub>28</sub> H <sub>50</sub>	( II, R=CH <sub>3</sub> )
27 $\alpha\alpha$ R	+ 20S $\alpha\alpha\alpha$ cholestane	C <sub>27</sub> H <sub>48</sub>	(III, R=H)
29d $\beta$ S	20S $\beta\alpha$ 24-ethyl-diacholestane	C <sub>29</sub> H <sub>52</sub>	( II, R=C <sub>2</sub> H <sub>5</sub> )
27 $\beta\beta$ R*	+ 20R $\alpha\beta\beta$ cholestane	C <sub>27</sub> H <sub>48</sub>	( IV, R=H)
27 $\beta\beta$ S*	20S $\alpha\beta\beta$ cholestane	C <sub>27</sub> H <sub>48</sub>	( IV, R=H)
28d $\alpha$ R	+ 20R $\alpha\beta$ 24-methyl-diacholestane	C <sub>28</sub> H <sub>50</sub>	( II, R=CH <sub>3</sub> )
27 $\alpha\alpha$ R	20R $\alpha\alpha\alpha$ cholestane	C <sub>27</sub> H <sub>48</sub>	(III, R=H)
29d $\beta$ R	20R $\beta\alpha$ 24-ethyl-diacholestane	C <sub>29</sub> H <sub>52</sub>	( I, R=C <sub>2</sub> H <sub>5</sub> )
29d $\alpha$ R	20R $\alpha\beta$ 24-ethyl-diacholestane	C <sub>29</sub> H <sub>52</sub>	( II, R=C <sub>2</sub> H <sub>5</sub> )
28 $\alpha\alpha$ S	20S $\alpha\alpha\alpha$ 24-methyl-cholestane	C <sub>28</sub> H <sub>50</sub>	(III, R=CH <sub>3</sub> )
28 $\beta\beta$ R*	20R $\alpha\beta\beta$ 24-methyl-cholestane	C <sub>28</sub> H <sub>50</sub>	( IV, R=CH <sub>3</sub> )
29d $\alpha$ S	+ 20R $\alpha\beta$ 24-ethyl-diacholestane	C <sub>29</sub> H <sub>52</sub>	( II, R=C <sub>2</sub> H <sub>5</sub> )
28 $\beta\beta$ S*	20S $\alpha\beta\beta$ 24-methyl-cholestane	C <sub>28</sub> H <sub>50</sub>	( IV, R=CH <sub>3</sub> )
28 $\alpha\alpha$ R	20R $\alpha\alpha\alpha$ 24-methyl-cholestane	C <sub>28</sub> H <sub>50</sub>	(III, R=CH <sub>3</sub> )
29 $\alpha\alpha$ S	20S $\alpha\alpha\alpha$ 24-ethyl-cholestane	C <sub>29</sub> H <sub>52</sub>	(III, R=C <sub>2</sub> H <sub>5</sub> )
29 $\beta\beta$ R*	20R $\alpha\beta\beta$ 24-ethyl-cholestane	C <sub>29</sub> H <sub>52</sub>	( IV, R=C <sub>2</sub> H <sub>5</sub> )
29 $\beta\beta$ S*	20S $\alpha\beta\beta$ 24-ethyl-cholestane	C <sub>29</sub> H <sub>52</sub>	( IV, R=C <sub>2</sub> H <sub>5</sub> )
29 $\alpha\alpha$ R	20R $\alpha\alpha\alpha$ 24-ethyl-cholestane	C <sub>29</sub> H <sub>52</sub>	(III, R=C <sub>2</sub> H <sub>5</sub> )
M30 $\alpha\alpha$	$\alpha\alpha$ 4-methyl-24-ethyl-cholestane	C <sub>30</sub> H <sub>54</sub>	

M30D	$\alpha\alpha$ 4,23,24-trimethyl-cholestane	$C_{30}H_{54}$	
30 $\alpha\alpha$ S	20S $\alpha\alpha\alpha$ 24-propyl-cholestane	$C_{30}H_{54}$	( IV, R=C <sub>3</sub> H <sub>7</sub> )
30 $\beta\beta$ R*	20R $\alpha\beta\beta$ 24-propyl-cholestane	$C_{30}H_{54}$	( V, R=C <sub>3</sub> H <sub>7</sub> )
30 $\beta\beta$ S*	20S $\alpha\beta\beta$ 24-propyl-cholestane	$C_{30}H_{54}$	( IV, R=C <sub>3</sub> H <sub>7</sub> )
30 $\alpha\alpha$ R	20R $\alpha\alpha\alpha$ -24-propyl-cholestane	$C_{30}H_{54}$	( IV, R=C <sub>3</sub> H <sub>7</sub> )

\* Compounds identified and quantified in M/Z 218 fragmentograms



STRUCTURES REPRESENTING STERANES

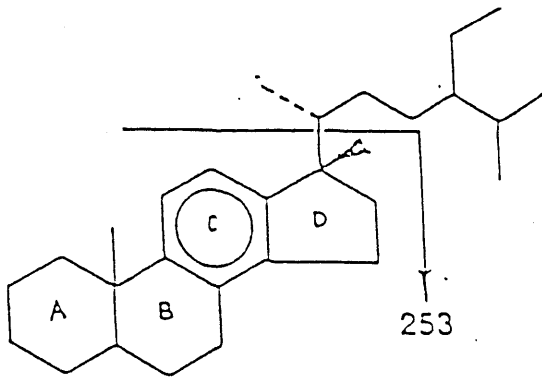


**Mass Fragmentograms representing Monoaromatic Steranes  
(M/Z 253)**

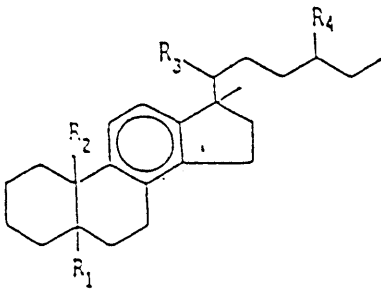
Description of C-ring monoaromatic steroid hydrocarbons

Peak	Substituents				Abbreviation of Compound
	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	R <sub>4</sub>	
A1					C <sub>21</sub> M
B1					C <sub>22</sub> MA
C1	β(H)	CH <sub>3</sub>	S(CH <sub>3</sub> )	H	βSC <sub>27</sub> MA
	β(H)	CH <sub>3</sub>	R(CH <sub>3</sub> )	H	βRC <sub>27</sub> MA
D1	CH <sub>3</sub>	H	R(CH <sub>3</sub> )	H	RC <sub>27</sub> DMA
	α(H)	CH <sub>3</sub>	S(CH <sub>3</sub> )	H	αSC <sub>27</sub> MA
E1	β(H)	CH <sub>3</sub>	S(CH <sub>3</sub> )	CH <sub>3</sub>	βSC <sub>28</sub> MA
	CH <sub>3</sub>	H	S(CH <sub>3</sub> )	CH <sub>3</sub>	SC <sub>28</sub> DMA
F1	α(H)	CH <sub>3</sub>	R(CH <sub>3</sub> )	H	αRC <sub>27</sub> MA
	α(H)	CH <sub>3</sub>	S(CH <sub>3</sub> )	CH <sub>3</sub>	αSC <sub>28</sub> MA
	β(H)	CH <sub>3</sub>	R(CH <sub>3</sub> )	CH <sub>3</sub>	βRC <sub>28</sub> MA
G1	CH <sub>3</sub>	H	R(CH <sub>3</sub> )	CH <sub>3</sub>	RC <sub>28</sub> DMA
	β(H)	CH <sub>3</sub>	S(CH <sub>3</sub> )	C <sub>2</sub> H <sub>5</sub>	βSC <sub>29</sub> MA
	CH <sub>3</sub>	H	S(CH <sub>3</sub> )	C <sub>2</sub> H <sub>5</sub>	SC <sub>29</sub> DMA
	α(H)	CH <sub>3</sub>	R(CH <sub>3</sub> )	CH <sub>3</sub>	αRC <sub>28</sub> MA
H1	β(H)	CH <sub>3</sub>	R(CH <sub>3</sub> )	C <sub>2</sub> H <sub>5</sub>	βRC <sub>29</sub> MA
	CH <sub>3</sub>	H	R(CH <sub>3</sub> )	C <sub>2</sub> H <sub>5</sub>	RC <sub>29</sub> DMA
I1	α(H)	CH <sub>3</sub>	R(CH <sub>3</sub> )	C <sub>2</sub> H <sub>5</sub>	αRC <sub>29</sub> MA

STRUCTURES REPRESENTING MONOAROMATIC STERANES



I

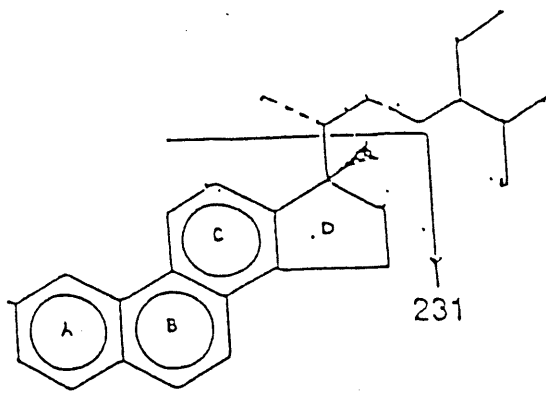


**Mass Fragmentograms representing Triaromatic Steranes  
(M/Z 231)**

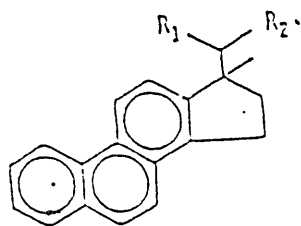
Description of ABC-ring triaromatic steroid hydrocarbons

Peak	Substituents		Abbreviation of Compound
	R <sub>1</sub>	R <sub>2</sub>	
a1	CH <sub>3</sub>	H	C <sub>20</sub> TA
b1	CH <sub>3</sub>	CH <sub>3</sub>	C <sub>21</sub> TA
c1	S(CH <sub>3</sub> )	C <sub>6</sub> H <sub>1-3</sub>	SC <sub>26</sub> TA
d1	R(CH <sub>3</sub> )	C <sub>6</sub> H <sub>13</sub>	RC <sub>26</sub> TA
	S(CH <sub>3</sub> )	C <sub>7</sub> H <sub>15</sub>	SC <sub>27</sub> TA
e1	S(CH <sub>3</sub> )	C <sub>8</sub> H <sub>17</sub>	SC <sub>28</sub> TA
f1	S(CH <sub>3</sub> )	C <sub>7</sub> H <sub>15</sub>	RC <sub>27</sub> TA
g1	R(CH <sub>3</sub> )	C <sub>8</sub> H <sub>17</sub>	RC <sub>28</sub> TA

STRUCTURES REPRESENTING TRIAROMATIC STERANES



II



## Stable Carbon Isotope Ratio Mass Spectrometry

Carbon isotope analysis is performed on a dual inlet VG SIRA 10 instrument. The combustion of the samples is performed by a Carlo Erba EA 1108 element analyser directly connected to the inlet system of the mass spectrometer.

The combustion temperature is 1020°C and the carrier gas used was Helium. After the combustion H<sub>2</sub>O and CO<sub>2</sub> are trapped in individual cool traps. The CO<sub>2</sub> gas is then heated up before admission into the mass spectrometer. The whole operation is controlled by an IBM PC50 computer system.

### δ-values

The isotope ratios are given as δ-values in ‰ versus the PDB-standard:

$$\delta^{13}\text{C} = \left( \frac{R_{\text{sample}} - R_{\text{standard}}}{R_{\text{standard}}} \right) \times 1000$$
$$R = \frac{^{13}\text{C}}{^{12}\text{C}}$$

The PDB-standard (a marine chalk of the Pee Dee-formation, USA) was created by Craig 1957. All results of <sup>13</sup>C/<sup>12</sup>C-analysis of organic matter today are calculated (Craig correction) against this international standard.

### Reproducibility

The precision of the combustion system and the mass spectrometer is controlled by determination of an international calibrated standard, NBS22 oil and a house standard carbon. Replicate analyses are also performed on samples.

## **APPENDIX 1:**

## **TABLES**

- 1-

Table 1 : Lithology description for well NOCS 16/1-4

Depth unit of measure: m

Depth	Type	Grp	Frm	Age	Trb	Sample
Int	Cvd	TOC%	%	Lithology description		
1536.00						0017
			100	Sh/Clst: lt gy to m gy, slt		0017-1L
1549.26	ccp					0003
			100	S/Sst : lt or to w, f, l		0003-1L
1549.80	ccp					0024
			100	Slst : lt gy to lt gy w, s, f, l		0024-1L
1553.52	ccp					0005
			100	S/Sst : lt or to w, f, l		0005-1L
1558.90	ccp					0006
			100	Sh/Clst: drk gy to gn pu		0006-1L
1562.47	ccp					0004
			100	Sh/Clst: drk gy to drk gn gy, calc, sft		0004-1L
1567.68	ccp					0001
			100	Sh/Clst: drk gy, pyr		0001-1L



- 2-

Table 1 : Lithology description for well NOCS 16/1-4

Depth unit of measure: m

Depth	Type	Grp	Frm	Age	Trb	Sample
Int	Cvd	TOC%	%	Lithology description		
1590.67	ccp					0002
			100	S/Sst : lt or to w, f, l		0002-1L
1597.00	ccp					0023
			100	S/Sst : lt gy to lt gy w, f, l		0023-1L
1599.56	ccp					0007
			100	S/Sst : lt or to w, f, l		0007-1L
1606.72	ccp					0008
			100	S/Sst : lt or to w, f, l		0008-1L
1696.90	ccp					0009
			100	Sh/Clst: gy blk to drk gy, slt		0009-1L
1698.88	ccp					0010
			100	Sh/Clst: m gy to drk gy, slt, evap		0010-1L
1702.54	ccp					0011
			100	Sh/Clst: drk gy to m gy, slt		0011-1L
1708.66	ccp					0012
			100	Sh/Clst: drk gy to m gy, slt		0012-1L



- 4-

Table 1 : Lithology description for well NOCS 16/1-4

Depth unit of measure: m

Depth	Type	Grp	Frm	Age	Trb	Sample
Int	Cvd	TOC%	%	Lithology description		
1872.00	eom			Basement(?)		0040
			100	Other		0040-1L
1875.00						0021
			50	Sh/Clst: lt gy to m gy, slt		0021-1L
			35	Other : gy pi		0021-2L
			15	Ca : lt gy w to w, chk		0021-3L
1881.00						0020
			50	Sh/Clst: lt gy to m gy, slt		0020-1L
			40	Other : gy pi		0020-2L
			10	Ca : lt gy w to w, chk		0020-3L
1881.00	eom					0041
			100	Other		0041-1L
1888.00	eom					0042
			100	Other		0042-1L
1914.00						0022
			70	S/Sst : m brn to w, f, crs, l		0022-1L
			30	Sh/Clst: drk gy to gy blk, slt		0022-2L

Table 2a: Rock-Eval table for well NOCS 16/1-4

Depth unit of measure: m

Depth	Typ	Lithology	S1	S2	S3	S2/S3	TOC	HI	OI	PP	PI	Tmax	Sample
1536.00	cut	Sh/Clst: lt gy to m gy	0.80	6.00	2.35	2.55	1.13	531	208	6.8	0.12	369	0017-1L
1549.26	ccp	S/Sst : lt or to w	2.86	0.69	0.72	0.96	-	-	-	3.5	0.81	355	0003-1L
1549.80	ccp	Sltst : lt gy to lt gy w	1.80	0.91	0.72	1.26	0.26	350	277	2.7	0.66	353	0024-1L
1553.52	ccp	S/Sst : lt or to w	1.55	0.62	0.61	1.02	-	-	-	2.2	0.71	420	0005-1L
1558.90	ccp	Sh/Clst: drk gy to gn pu	0.35	2.76	0.85	3.25	1.82	152	47	3.1	0.11	396	0006-1L
1562.47	ccp	Sh/Clst: drk gy to drk gn gy	0.08	0.84	0.83	1.01	0.46	183	180	0.9	0.09	456	0004-1L
1567.68	ccp	Sh/Clst: drk gy	0.31	5.94	1.12	5.30	1.71	347	65	6.3	0.05	364	0001-1L
1590.67	ccp	S/Sst : lt or to w	4.87	0.68	0.69	0.99	-	-	-	5.5	0.88	357	0002-1L
1597.00	ccp	S/Sst : lt gy to lt gy w	1.30	0.47	0.50	0.94	-	-	-	1.8	0.73	353	0023-1L
1599.56	ccp	S/Sst : lt or to w	1.21	0.57	0.51	1.12	-	-	-	1.8	0.68	348	0007-1L
1606.72	ccp	S/Sst : lt or to w	2.27	0.76	0.61	1.25	-	-	-	3.0	0.75	348	0008-1L
1696.90	ccp	Sh/Clst: gy blk to drk gy	0.25	3.42	0.15	22.80	1.68	204	9	3.7	0.07	426	0009-1L
1698.88	ccp	Sh/Clst: m gy to drk gy	0.26	1.67	0.18	9.28	1.26	133	14	1.9	0.13	416	0010-1L
1702.54	ccp	Sh/Clst: drk gy to m gy	0.27	3.12	0.14	22.29	1.48	211	9	3.4	0.08	422	0011-1L
1708.66	ccp	Sh/Clst: drk gy to m gy	0.30	3.40	0.16	21.25	1.36	250	12	3.7	0.08	424	0012-1L

Table 2a: Rock-Eval table for well NOCS 16/1-4

Depth unit of measure: m

Depth	Typ	Lithology	S1	S2	S3	S2/S3	TOC	HI	OI	PP	PI	Tmax	Sample
1710.49	ccp	Sh/Clst: m gy	0.23	3.16	0.14	22.57	1.45	218	10	3.4	0.07	422	0013-1L
1721.82	ccp	Sh/Clst: m gy to drk gy	0.16	3.11	0.09	34.56	1.18	264	8	3.3	0.05	423	0014-1L
1723.97	ccp	Sh/Clst: m gy to drk gy	0.29	5.65	0.18	31.39	1.73	327	10	5.9	0.05	423	0015-1L
1733.00	swc	Sh/Clst: m gy to drk gy	0.41	4.51	0.19	23.74	1.86	242	10	4.9	0.08	428	0016-1L
1758.00	cut	Sh/Clst: lt gy to m gy	0.72	3.81	1.20	3.17	0.90	423	133	4.5	0.16	358	0018-1L
1761.00	cut	Sh/Clst: lt gy to m gy	0.55	2.53	1.25	2.02	0.51	496	245	3.1	0.18	355	0019-1L
1875.00	cut	Sh/Clst: lt gy to m gy	0.34	1.16	0.38	3.05	0.31	374	123	1.5	0.23	359	0021-1L
1881.00	cut	Sh/Clst: lt gy to m gy	0.53	1.83	0.46	3.98	0.45	407	102	2.4	0.22	359	0020-1L
1914.00	cut	S/Sst : m brn to w	0.24	0.62	0.28	2.21	-	-	-	0.9	0.28	343	0022-1L

Table 2B: ROCK-EVAL TABLE, STANDARDS FOR WELL NOCS 16/1-4

S1	S2	S3	S2/S3	TOC	HI	OI	PP	PI	Tmax
0.45	18.71	1.97	9.49	4.21	444	46	19.16	0.02	421
0.43	18.85	1.96	9.61	4.24	444	46	19.28	0.02	423

Table 3A: Results of TLC-FID analysis: Absolute yields in mg/g rock for well NOCS 16/1-4

Depth unit of measure: m

<u>Depth</u>	<u>S Tp</u>	<u>F Tp</u>	<u>Lithology</u>	<u>Sat HC</u>	<u>Aro HC</u>	<u>Resins</u>	<u>Asp</u>	<u>Tot HC</u>	<u>Tot Pol</u>	<u>Tot EOM</u>	<u>Sample</u>
	RFT 2A		BULK FRACTION	-	-	-	-	-	-	-	0030-0B
1536.00	ccp L		SHALE/CLAYSTONE	0.085	0.000	0.060	0.004	0.085	0.064	0.149	0017-1L
1549.26	ccp L		SANDSTONE/SAND	0.000	0.000	1.583	0.036	0.000	1.619	1.619	0003-1L
1553.52	ccp L		SANDSTONE/SAND	0.113	0.031	1.185	0.012	0.144	1.197	1.341	0005-1L
1567.68	ccp L		SHALE/CLAYSTONE	0.000	0.000	0.106	0.000	0.000	0.106	0.106	0001-1L
1590.67	ccp L		SANDSTONE/SAND	0.085	0.045	3.865	0.035	0.130	3.900	4.030	0002-1L
1606.72	ccp L		SANDSTONE/SAND	0.424	0.000	1.669	0.007	0.424	1.676	2.100	0008-1L
1708.66	ccp L		SHALE/CLAYSTONE	0.100	0.000	0.094	0.000	0.100	0.094	0.194	0012-1L
1723.97	ccp L		SHALE/CLAYSTONE	0.119	0.079	0.095	0.008	0.198	0.103	0.301	0015-1L
1864.00	eom B		BULK FRACTION	-	-	-	-	-	-	-	0025-0B
1872.00	eom B		BULK FRACTION	-	-	-	-	-	-	-	0026-0B
1881.00	cut L		SHALE/CLAYSTONE	0.132	0.340	0.790	0.018	0.472	0.808	1.280	0020-1L
1881.00	eom B		BULK FRACTION	-	-	-	-	-	-	-	0027-0B
1888.00	eom B		BULK FRACTION	-	-	-	-	-	-	-	0028-0B

Schlumberger

GECO-PRAKLA

GEOLAB  NOR

Table 3B: Results of TLC-FID analysis: Rel. percentages of sep. fractions for well NOCS 16/1-4

Depth unit of measure: m

Depth	S Tp	F Tp	Lithology	Sat HC	Aro HC	Resins	Asp	Tot HC	Tot Pol	Sample
	RFT	2A	BULK FRACTION	64.18	18.07	17.54	0.21	82.25	17.75	0030-0B
1536.00	ccp	L	SHALE/CLAYSTONE	57.05	0.00	40.27	2.68	57.05	42.95	0017-1L
1549.26	ccp	L	SANDSTONE/SAND	0.00	0.00	97.78	2.22	0.00	100.00	0003-1L
1553.52	ccp	L	SANDSTONE/SAND	8.43	2.31	88.37	0.89	10.74	89.26	0005-1L
1567.68	ccp	L	SHALE/CLAYSTONE	0.00	0.00	100.00	0.00	0.00	100.00	0001-1L
1590.67	ccp	L	SANDSTONE/SAND	2.11	1.12	95.91	0.87	3.23	96.77	0002-1L
1606.72	ccp	L	SANDSTONE/SAND	20.19	0.00	79.48	0.33	20.19	79.81	0008-1L
1708.66	ccp	L	SHALE/CLAYSTONE	51.55	0.00	48.45	0.00	51.55	48.45	0012-1L
1723.97	ccp	L	SHALE/CLAYSTONE	39.53	26.25	31.56	2.66	65.78	34.22	0015-1L
1864.00	eom	B	BULK FRACTION	15.89	6.90	75.13	2.08	22.79	77.21	0025-0B
1872.00	eom	B	BULK FRACTION	22.01	8.80	67.72	1.47	30.82	69.18	0026-0B
1881.00	cut	L	SHALE/CLAYSTONE	10.31	26.56	61.72	1.41	36.87	63.12	0020-1L
1881.00	eom	B	BULK FRACTION	16.13	8.59	71.03	4.25	24.72	75.28	0027-0B
1888.00	eom	B	BULK FRACTION	61.20	16.46	21.08	1.27	77.65	22.35	0028-0B